FINAL EPORT

on

ISR Supplemented Studies of the CUSP and POLAR CAP (Grant No F 61776-99-WE 001)

by

Professor Alv Egeland, Principal investigator

Department of Physics
P.O. Box 1048, Blindern - N-0316 Oslo – Norway
e-mail: alv.egeland@fys.uio.no

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	November 1999	Final Report

4. TITLE AND SUBTITLE

ISR Supplemented Study of the Cusp and Polar Cap

5. FUNDING NUMBERS

F61775-99-WE001

6. AUTHOR(S)

Professor Alv Egeland

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

University of Oslo
PO Box 1048 Blindern
Oslo N-0316
Norway

8. PERFORMING ORGANIZATION REPORT NUMBER

N/A

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

EOARD
PSC 802 BOX 14
FPO 09499-0200

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

SPC 99-4001

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

A

13. ABSTRACT (Maximum 200 words)

This report results from a contract tasking University of Oslo as follows: The contractor will investigate the altitude range of the optical red line emission from noon aurorae, and also the transient upwelling of the thermosphere as a signature of transient entry of ionospheric plasma through the cusp into the polar cap night-time ionosphere.

14. SUBJECT TERMS

EOARD, Space Science, radar, Ionosphere, Atmospheric Emission

15. NUMBER OF PAGES

6

16. PRICE CODE

N/A

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19, SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UL

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. 239-18
298-102

Final Report
on
ISR Supplemented Studies of the CUSP and POLAR CAP

Background Information

Svalbard is a unique place in the northern hemisphere for studies of dayside auroras and related phenomena within the cusp, cleft, low latitude boundary layer, mantle and polar cap. It is nearly 12 hours separated in magnetic time from the Alaska sector and its conjugacy to stations in Antarctica makes Svalbard even more attractive. The Svalbard climate – due to the Gulf Stream -is unusual mild. Thus, there is no other places at the same latitudes as our stations on Svalbard in which the comforts of modern living can be enjoyed, and is so accessible from the world's largest metropolises. In addition, we have a long tradition for auroral research in Norway.

Ny Ålesund (geogr. lat. 78.9^{0}N; geomagnetic lat. 75.3$^0\Lambda$) and Longyearbyen (geogr. lat. 78.2^{0}N; and geom. lat 74.3$^0\Lambda$) are the master stations in our Svalbard network. The main optical instruments are meridian scanning photometers (MSP) and CCD optical imagers (TV-cameras), at different wavelengths.

The new EISCAT Svalbard Incoherent Scatter Radar (ESR) at Longyearbyen has been in operation during this contract period. The ESR is a third generation research instrument of highest standard. Its 32-meter diameter antenna is movable over 360^0 in azimuth and from 0 to 180^0 in elevation. This Radar is located on the Gruve 7 - mountain, near the Longyearbyen auroral station. A new antenna allowing simultaneous observations in two different directions is under construction. When ESR is in full operation it will vastly enhance our rate of progress in the key areas of the scientific field of this Grant.

It was not until the 1980s, that a new research program to focus on the cusp and polar cap ionosphere and its coupling to the underlying neutral atmosphere, to the magnetosphere and solar wind beyond, and to global processes was created. An international polar network of optical, radio, and HF sounder sites was established involved primarily Svalbard, but also Greenland.

Observations and Results obtained

The ionospheric cusp/cleft dynamics above Svalbard have been investigated by multi-instrument techniques including radars, optics and ionospheric tomography during several campaigns. Below is given a brief report on the major results:

For more details the reader is referred to the publication listed at the end.

The most unique feature of magnetic reconnection testable from ground is the IMF B_Y control of the zonal motion – the Svalbard-Mansurov effect. The IMF B_Y control of the motion pattern and the location of cusp auroral activity has been monitored in a case when the B_Y component of the interplanetary magnetic field (IMF) went from a large negative to a large positive value in the course of say maximum 20 minutes. An IMF B_Y regulated shift in the longitudinal position of the auroral cusp has been documented. The zonal shift of the cusp centre is in magnetic local time . The observations indicate that the cusp reconfigured within few minutes after the B_Y polarity change imposed on the magnetopause.

Observations have been conducted of enhancements in the electron density of the ionospheric F-region associated by cusp/cleft particle precipitation at the dayside entry to the polar-cap convection flow. Measurements by meridian scanning photometer and all-sky camera of optical red-line emissions from aurora are used to identify latitudinally-narrow bands of soft-particle precipitation responsible for structured enhancements in electron density determined from images obtained by radio tomography.

A few cases have been compared in which the electron density features with size scales (several hundred kilometres) and magnitudes commensurate with those of patches are shown to be formed by precipitation at the entry region to the anti-sunward flow. The life-times of such structures will be dependent on the spectrum of the precipitation and the consequent height of the ionisation being created. In one case the spectrum of the incoming particles results in ionisation created for the most part below 250 km so that the patch will persist only for minutes after convecting away from the auroral source region. However, in a second example, at a time when the plasma density of the solar wind was particularly high, a substantial part of the particle-induced enhancement formed above 250 km. It is suggested that, with the reduced recombination loss in the upper F-region, this structure will retain form as a patch during passage in the anti-sunward flow across the polar cap. The present study indicates that cusp/cleft particle precipitation alone may on occasion be capable of forming polar-cap patches. The solar wind density was unusually high on this particular day, and more cases have to be investigated before any decisive conclusion can be drawn on the relative importance of cusp particle precipitation compared to the other competing mechanisms.

Regions of enhanced spectral width observed by coherent HF radars on the high-latitude dayside is broadly used as an indicator of magnetosheath precipitation. In order to test the HF spectral width criterion of 220 m/s as a cusp identifier, we have correlated the equatorward 630.0 nm cusp boundary with the equatorward boundary of enhanced HF spectral widths. The correlation study is based on extended time sequences of boundary motions observed simultaneously in space and time by the meridian scanning photometer at Ny-Ålesund (Svalbard), and all-sky imager located at Longyearbyen (Svalbard), and the Finland CUTLASS radar. For cases of good backscatter and IMF $B_Z < 0$ there is an excellent relationship between the equatorward boundary of spectral width enhancement and the equatorward boundary of cusp/cleft precipitation. NOAA particle measurements relate this boundary to the open closed field line boundary. However, as will be demonstrated, cusp/cleft auroral activity does not always stimulate radar backscatter, and hence the coherent HF radar technique sometimes fails to pick up regions of magnetosheath preciptiation.

The combination of ESR (EISCAT Svalbard Radar) and optics provide new opportunities to study detailed dynamics of the ionopsheric cusp. A simple convection mode experiment with the ESR pointing towards magnetic north at an elevation angle of 45^0 was run. The radar was oriented within the plane swept by Ny-Ålesund scanning photometer. This configuration enabled an investigation of the IMF B_Y regulation of the cusp inflow region. When the ESR was sitting within the return flow, the convection streamlines were oriented east-west along the auroral arcs (transition discontinuity and no plasma transport into the polar cap). When the ESR was located within the cusp inflow region, plasma flow moved perpendicular to the arc (rotational discontinuity and plasma transport across the polar cap boundary). Furthermore, an experimental evidence of plasma incompressibility has been documented.

I would also like to mention that:

An international project meeting was arranged at University of Oslo between 10 and 12. May. We spend two days discussing the data from our Svalbard activity in relation to relevant satellite observations.

Two new rocket proposals for further studies of cusp structures and dynamics – with Ny Ålesund launches – have been send to NASA. Air Force Research Lab., Hanscom AFB is involved in both proposals. Before the end of this year we will have the final answer.

Dr. Carlson, Professor Sandholdt and I are working hard on a new text book on Dayside and Polar Cap Auroras to be published in year 2000.

PERSONNEL

The key personnel in this research project:

Alv Egeland,	**University of Oslo, UiO**
Espen Trondsen	**« «**
Jøran Moen	**UNIS, Svalbard**

and graduate students at both UNIS and UiO.

Dr. Jøran Moen, Dag Lorentzen and his graduate students have been responsible for the observations at Longyearbyen, while the Plasma and Space Physics group at University of Oslo has carried out the ad hoc observations at Ny Ålesund.

A list of Auroral observations from Svalbard during the winter 1998/99 is enclosed:

Auroral observations (clear sky) during the winter 98/99

- **Dec. 12, 1998; 0500-1100 UT (interesting activity).**
- **Dec. 13, 1998; 0500-1200 UT.**
- **Dec. 15, 1998; 0500-1100 UT.**
- **Dec. 16, 1998; 0500-1100 UT (interesting activity).**
- **Dec. 18, 1998; 0500-1100 UT.**
- **Dec. 19, 1998; 0500-1100 UT.**
- **Dec. 20, 1998; 0500-1100 UT.**
- **Dec. 21, 1998; 0500-0700 UT.**
- **Jan. 8, 1998; 0500-1100 UT (interesting).**
- **Jan. 9, 1999; 0500-1000 UT; 1920-2400 UT.**
- **Jan. 10, 1999; 0000-1240 UT (interesting).**
- **Jan. 14, 1999; 0420-1100 UT (interesting).**

- **Jan. 15, 1999; 0415-1100 UT (interesting).**
- **Jan. 16, 1999; 0410-0490 UT.**
- **Jan. 17, 1999; 0630-0700 UT.**
- **Jan. 19, 1999; 0420-1226 UT (interesting).**
- **Jan. 20, 1999; 0430-0530 UT.**
- **Jan. 21, 1999; 0410-1000 UT (interesting) .**
- **Jan. 22, 1999; 0330-0910 UT.**
- **Jan. 23, 1999; 0800-0915 UT.**

References and publications

A new text book relevant to this research project is under preparation.

Egeland, A., H. Carlson and P. E. Sandholt: Dayside and Polar Cap Auroras. Kluwer Academic Publ. Dordrecht, 2000 (≈ 250 pages).

Scientific papers in journals and proceedings relevant to this research project.

Egeland, A.: Dayside and polar cap auroral studies in the next millenium: p. 382-389 in Proceedings 14th ESA Symposium in Postdam, Germany, 31 May – 3 June, 1999 (ESA SP-437, Sept. 1999).

Egeland, A.: Combined Ground and In-Situ Measurements Needed in Solar-Terrestrial Research. Proc., International Symposium on Environmental Research in the Antarctic, Nat.Inst. Pol. Res. Tokyo, Spec. Issue **52,** pp. 1-13 (1998).

Farrugia, C. J., P. E. Sandholt, J. Moen, and R. L. Arnoldy, Unusual features of the January 1997 magnetic cloud and their effect on optical dayside auroral signatures, *Geophys. Res. Lett.*, **25,** 3051-3054, 1998.

Liao, I. and A. Egeland: ELF/VLF Emissions of Dayside Cleft and Correlations between Emissions and Geomagnetic Disturbances. Chinese Journal of Geophysics **38**, 165-180 (1998).

Lorentzen, D. A., and J. Moen: Auroral proton and electron signatures in the dayside aurora, *Submitted to J. Geophys. Res.,* April 1999.

Maynard, N. C., W. J. Burke, R. F. Pfaff, E. Weber. D.D. Ober, D. R. Weimer, J. Moen, S. Milan, K. Måseide, P. E. Sandholt, A. Egeland, F. Søraas, R. Lepping, S. Bounds, M. H. Acuna, H. Freudenreich, L. C. Gentile, D. A. Hardy, J. A. Holtet, M. Lester, J. S. Machuzak., P. Ning, J. Stadsnes, and T. Van Eyken: Driving dayside convection with northward IMF: observations of a sounding rocket from Svalbard, *Accepted for publication in J. Geophys. Res.,* May 1999.

Milan, S. E., T. K. Yoeman, M. Lester, J. Moen, P. E. Sandholt, Post-noon two-minute period pulsating aurora and their relationship to the dayside convection pattern, *Ann. Geophyicae,* 17, 877.891, 1999.

Moen, J., H. C. Carlson and P. E. Sandholt: Continuous observations of cusp auroral dynamics in response to an IMF B_y polarity change, *Geophys. Res. Lett.*, *26*, 1243-1246, 1999.

Moen, J., P. E. Sandholt and A. Egeland: Pre- and post-noon asymmetry in dayside auroral activity and convection related to solar-wind-magnetosphere interactions. *Submitted to Adv. Space Res., August 1998.*

Moen, J., H. C. Carlson, S. Milan, N. Shumilov, B. Lybekk, P. E. Sandholt and M. Lester: On the correlation between cusp/cleft auroral activity and spectral width enhancement observed by coherent HF radar, in preparation for *Ann. Geophysicae,* spring 1999.

Ober, D. M., N. C. Maynard, W. J. Burke, J. Moen, A. Egeland, P. E. Sandholt, C. J. Farrugia, E. J. Weber, J. D. Scudder, and C. T. Russel: Mapping of ionospheric auroral features associated with the prenoon boundary layer to the magnetosphere, *in preparation for J. Geophys. Res.* Spring 1999.

Phryse, S. E., A. M. Smith, J. Moen and D. A. Lorentzen: Footprints of lobe reconnection observed in ionospheric electron density under steady northward IMF, *Geophys. Res. Lett.* 26, 25-28.

Pudovkin, M. and A. Egeland: Large-Scale Electric Fields in the Dayside Magnetosphere in Polar Cap Boundary Phenomena (eds. J. Moen et al.), NATO ASI vol. 509, Kluwer Academic Publishers, Dordrect, pp. 141-157 (1998).

Phryse, S. E., A. M. Smith, L. Kersley, I. K. Walker, C. N. Mitchell, J. Moen and R. Smith: Multi-instrument probing of the polar ionosphere under steady northward IMF. *Ann. Geophysicae,* in press, 1999.

Sandholt, P.E., J. Moen, P. Stauning, J.A. Holtet, S.W.H. Cowley, M. Lockwood, U.P. Lauvhaug, T. Hansen and A. Egeland: Temporal and spatial variability of auroral forms in the 10 – 14 MLT sector: Relàtionship to plasma convection and solar wind – magnetosphere coupling, Earth, Planets and Space, vol 50(8), pp. 663-682, 1998.

Sandholt, P.E., C.J. Farrugia, and S.W.H. Cowley: Pulsating cusp aurora for northward IMF, J. Geophys.Res., **103**, 26507-26520, 1998.

Sandholt, P.E., C.J. Farrugia, J. Moen, S.W.H. Cowley and B. Lybekk: Dynamic of the aurora and associated convection currents during a cusp bifurcation event, Geophys. Res..Lett., **25**, 4313-4316, 1998.

Sandholt, P.E. and C.J. Farrugia: The dynamic cusp aurora on November 30, 1997: Response to sourthward turning of the IMF, Ann. Geophys., in press, 1999.

Sandholt, P.E., C.J. Farrugia, S.W.H. Cowley, M. Lester, and J. Moen: Excitation and decay of lobe cell convection and its associate aurora, Geophys.Res.Lett., submitted June 1999.